N-576

AD658871

N 576

A STUDY OF THE CAUSES OF WIRE ROPE AND CABLE FAILURE IN OCEANOGRAPHIC SERVICE

ALL AMERICAN ENGINEERING COMPANY
BOX 1247, LANCASTER PIKE & CENTRE ROAD
WILMINGTON, DELAWARE 19899

43

Report No: N-576
Date: Sept. 1967

A Study of the Causes of Wire Rope and Cable Failure in Oceanographic Service

for the
U. S. Naval Oceanographic Office
Contract No. N62306-67-C-0287

Prepared by: R B Powell
R. B. Powell
Project Engineer

Approved by: S. G. Keahey
S. G. Keahey
Chief Engineer

ALL AMERICAN ENGINEERING COMPANY
WILMINGTON, DELAWARE

ABSTRACT

A study had been made, through a literature search and a survey of users and manufacturers, of the causes of failure of wire rope in marine and oceanographic applications. Although the material, construction, and application of wire rope were symptomatic of the majority of causes of failure, incorrect operating procedures and improper choice of related equipment were large factors. Recommendations are made for further investigation and development to improve performance and reliability.

TABLE OF CONTENTS

ACKNOWLEDGEMENT

Appreciation is expressed for the assistance and guidance of Mr. Lawrence Chase of the U. S. Naval Oceanographic Office, Scientific Officer for Contract N6206-67-C-0287, under which this study was authorized.

The consideration given by the following during visits and conferences was most helpful and is gratefully acknowledged:

U. S. Naval Oceanographic Office
Bergen Wire Rope Company
Bethlehem Steel Company
Battelle Memorial Institute
Packard Electric Division of General Motors Corporation
Hudson Labs. of Columbia University
Military Sea Transportation Service

Appreciation is also expressed to the many respondents to the mail survey. Recipients of the survey sheets are listed in Appendix A. In addition, the helpful letter comments from those who did not find the questionnaire applicable to their experience and the assistance in the literature search provided by the Defense Documentation Center are gratefully acknowledged.

SECTION I

INTRODUCTION

Many similarities can be drawn between the uses of wire rope and cable in oceanographic services and the various other uses to which this mechanical device has been applied for over a century. However, the comparatively recent growth in oceanographic work has placed increased emphasis upon some unique requirements of the wire rope and cable used in this field.

Long term moorings and deep anchoring of sophisticated equipment, deep sea corings and sampling, and the towing of a variety of instrumented packages at various depths and speeds place special requirements upon the line as well as the related equipment and handling procedures. Much work has been done; more work is required, not only with respect to the cable or wire rope itself but upon the complete data recovering system.

It is the objective of this study to indicate those areas of further research and development which will be most fruitful in bringing about increased performance and reliability.

SECTION II

APPROACH TO DATA

As an approach to the determination of the aforementioned areas of improvement, three basic methods of information gathering were used.

1. Review of much of the existing literature related to oceanographic uses of cable and wire rope.

2. Consultations with a number of users and suppliers of cables or wire rope with experience in marine or oceanographic fields.

3. Contacts with additional knowledgeable personnel by means of a mail survey in which a questionnaire type form was used (see Appendix A for sample survey sheets and list of recipients).

It is recognized that this approach does not explore an individual area in depth and that the information received is influenced by the personal interpretation of the informant as to what constitutes a problem area. However, in view of the wide scope of experience and knowledge represented by the information sources, a high degree of credence can be given to their accumulated opinions as an indicator for the direction of future effort.

SECTION III

DISCUSSION

1. CATEGORIES OF FAILURE CAUSES

The basic categories of probable failure cause for the purpose of this study were defined as:

a. Cable not suited to the application

b. Related equipment not suited to the application

c. Improper operating techniques used

d. Other causes

Various categories of failure are treated separately in the report, with a summary of the survey responses being presented first. This is followed by a general discussion based on information received through the literature search and consultations.

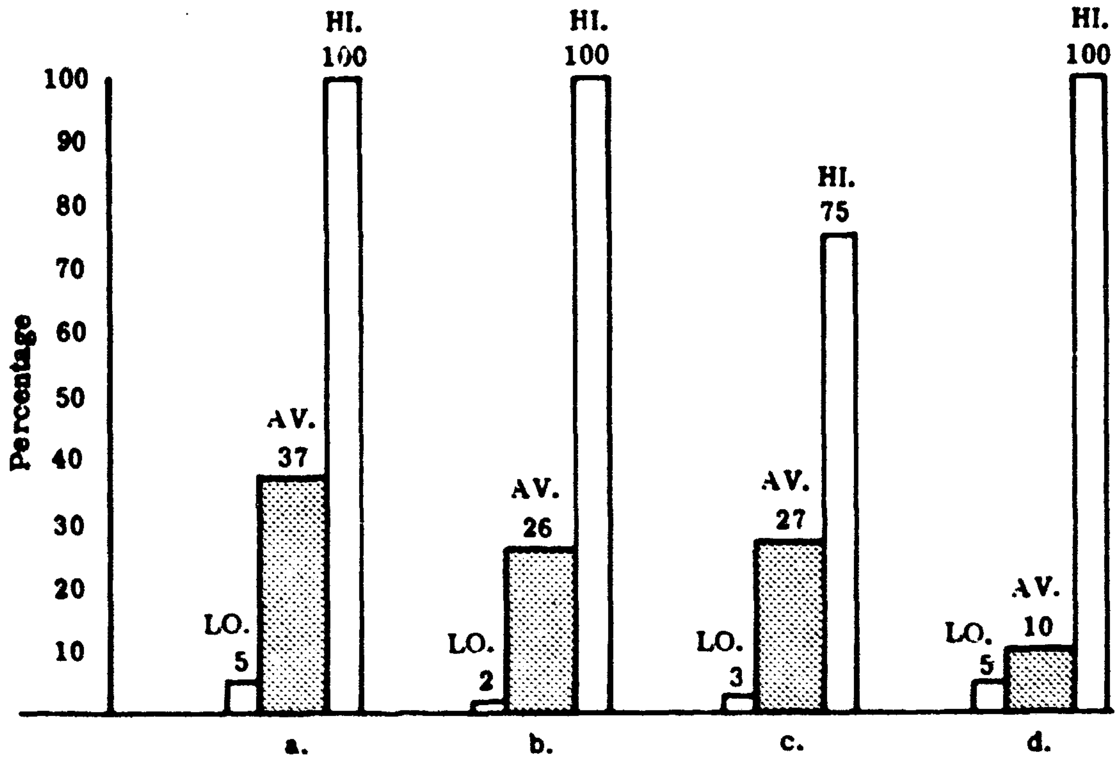
The conclusions and recommendations are presented as a group for all the areas under investigation.

In the summaries which begin each section of the discussion, three values are shown for each line from the survey sheets.

Average: The arithmetic average of the percentages assigned by the respondents. Unassigned or zero responses were considered as representing no activity in the area described by the particular line. The total number of respondents was used in determining the average even though some had assigned a zero value to the line.

High: The highest percentage (HI) assigned to a particular line.

Low: The lowest percentage (LO) other than zero assigned to a particular line.



a. Cable not suited to application

b. Related equipment (winches, sheaves, fittings, etc.) not suited to application

c. Improper operating techniques used

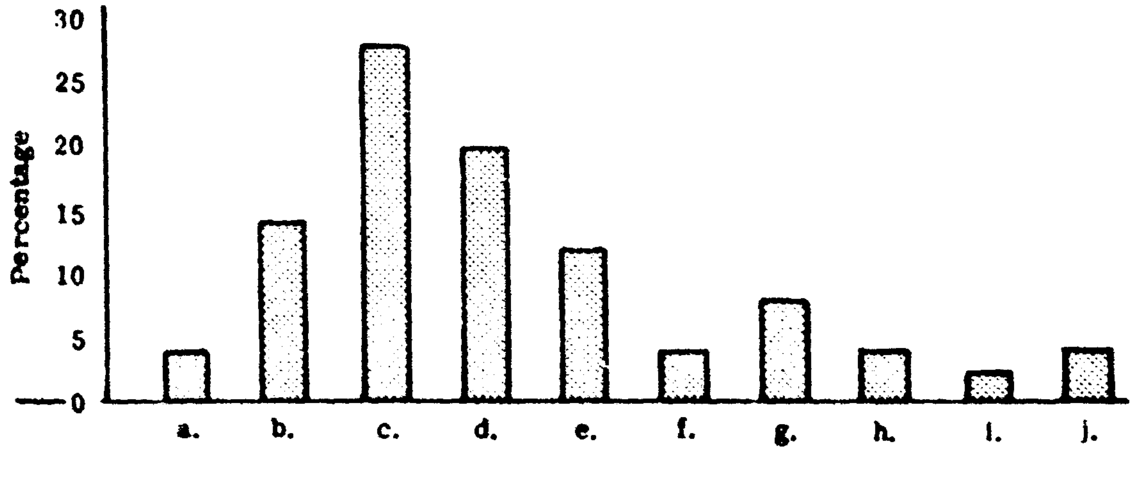
d. Other causes

PERCENTAGE RELATIONSHIP OF FAILURE CATEGORIES

(LOW - AVERAGE - HIGH)

2. FAILURES DUE TO CABLE

		(Percentages assigned)		
		AV.	HI.	LO.
a.	Inadequate rated strength	4	30	5
b.	Failure due to corrosion	14	80	5
c.	Improper construction selected	28	100	5
d.	Fatigue failure	20	60	5
e.	Shock or sudden load	12	75	5
f.	Vulnerability in handling	4	30	5
g.	Erosion, scuffing, local wear	8	30	5
h.	Lack of lubrication	4	20	5
i.	Variations in cable quality	2	20	5
j.	Other causes	4	60	3



a. Strength

Insofar as the rated strength is concerned, it is the general case that oceanographic work is performed with a lower factor of safety for the cable than is customary in most other types of service. The long lengths and moving platforms are inherent to the field, and the assignment of high safety factors is often impractical. Since this factor is usually a means of allowing for ignorance, lack of maintenance, and poor operating practice, oceanographers must face up to the fact that knowledge and discipline are their tools for improved wire rope and cable performance.

b. Corrosion

A number of methods to resist corrosion have been studied and advocated over the years. Among them are:

(1) Cladding: with zinc, copper, or aluminum

(2) Jacketting: with various plastics

(3) Exotic materials: stainless steels, DuPont MP35N, titanium, fiber glass, and others

(4) Cathodic protection systems: magnesium, aluminum, zinc

Generally, the economic considerations related to a particular program have a major influence upon the degree of corrosion protection employed.

c. Construction

Wire ropes are available in a somewhat bewildering number of constructions. Wire sizes, wires per strand, strands per rope, left hand, right hand, Lang lay, regular lay, fiber core or IWRC, are some of the characteristics which

influence performance and reliability. They emphasize the fact that a wire rope or cable is not a static device but a number of related parts which move with respect to each other with every change in cable loading or shape. F. Savastano of Bergen Wire Rope Co. in "Selecting Wire Rope for Oceanographic Applications", Under Sea Technology, Feb. 1967, states: "- - - there is no such thing as a standard oceanographic wire per se. The type and grade of wire rope used for oceanographic purposes will vary according to the nature of the application and the conditions of operation. Nevertheless, there has been a definite range of sizes and constructions and materials of wire rope normally used in the field."

A rather consistent problem in oceanographic service is the tendency of the rope to twist under load. Numerous manufacturers have produced wire rope and cables specially designed to reduce this tendency by balanced construction in which layers of different hand produce a neutral torque effect. The "3 by" construction, which eliminates the center core normally used in the 7 × 7 or 7 × 19 ropes, and is the shortest strand in the assembly, helps reduce the effects of rotation by eliminating the stretching and twisting of this member.

In "Wire Cables for Oceanographic Operations" J. C. Thompson and R. K. Logan, U. S. Navy Electronics Lab. state: "On the basis of the extensive tests reported here, the 3 × 19 cable is considered the most suitable of those now available for oceanographic applications, from the standpoint of its resistance to elastic and rotational stretch - - - -".

Unraveling under load is discussed in an article by H. M. Hoover of Ocean Science and Engineering, Inc. in the February 1965 issue of Geo-Marine Technology. The conclusion is: " - - - 6 × 19 wire is an order of magnitude worse than any of the torque-balanced ropes and appears unsuitable for any service wherein slack may be expected to come into the line after it is loaded."

d. Fatigue

A cycling of stresses through appreciable ranges occurs in the members of a wire rope or cable in almost every type of oceanographic service. Hoisting, towing, and mooring involve various degrees of cable motion from the extreme bending around a sheave to the high frequency, small amplitude motions which result from strumming. In each case changes of loading occur in the wire and relative motion between the wires takes place. Here, lubrication, surface finish, and proper support of the rope or cable do much to avoid the creation of stress raisers which have such an important relationship to the fatigue life of metal components.

The U. S. Naval Research Laboratory in its "Marine Corrosion Studies", NRL Memorandum Report 1574, November 1964, states: "The sequence of events leading to failure of high strength steels by stress-corrosion cracking is as follows: A pit or other surface irregularity slowly develops. When it has grown to a sufficient depth for the steel in question and the state of stress at that point, a stress-corrosion crack nucleates and grows. Stress corrosion will progress a critical amount for that steel and stress in the particular environment, and the remainder of the section snaps in brittle fracture."

e. Shock

Suddenly-applied loads either in line with or transverse to steel ropes and cables produce internal stress wave patterns which can be immediately destructive in their effect. The theory involved is complex and outside the scope of this report. Of significance is the fact that certain combinations of size and behavior of the submerged body, the cable, and the surface vessel can produce stresses in the cable which the normal factor of safety does not take into account. The immediate solution to the problem, recognized by many concerned parties, is the avoidance of slack in the line. Operating technique can be helpful, but a mechanism through which a constant line tension can be maintained is needed.

f. Handling

Abuse of wire rope and cable during storage and rigging is quite common. Here again, the lack of recognition that the rope or cable is in actuality an assembly of comparatively delicate, related parts is often to blame. Damage to one or several members can seriously affect the life and performance of the whole.

Proper methods of coiling and uncoiling, avoidance of loops and resultant kinks during rigging, and protection from sharp edges or heavy blows should be standard practice. Protection from the elements and avoiding the piling of heavy equipment or materials on coils or reels of rope, along with relubricating when necessary, are good storage procedures.

g. Erosion, Scuffing, and Local Wear

These factors as contributing causes to cable failure are most frequently taken care of by local protection through the use of jackets, fairleads, or sheaves. In some instances it is possible to shift the cable in order to distribute the wear to new areas, or to remove the worn section and splice the cable.

Most important is the consideration of the problems during the layout and rigging of the system so that preventive measures can be taken before serious damage occurs.

h. Lubrication

As with any device comprised of moving parts, lubrication of wire ropes is essential for optimum life and performance. Good lubrication protects against corrosion and reduces metal-to-metal contact between the individual wires and between the rope and the drums, sheaves, and fairleads with which it must operate.

In oceanographic service "field lubricating" cannot always be accomplished under favorable conditions, with the result that it may be neglected. Procedures and materials for adequately cleaning, flushing, and relubricating should be investigated.

However, where sample contamination, labor hours required, and the general messiness involved in using lubricated ropes outweigh a shortened life expectancy, operations are conducted with unlubricated ropes. In most cases these are of corrosion-resisting materials or of a zinc or aluminum clad wire, for which some premium must be paid.

i. Variations in Cable Quality

This is an area which the oceanographer can do little about except to work closely with the cable and wire rope manufacturers in their efforts to keep quality variances to a minimum. In cases of standard cables, quality control procedures will have been established. In new designs mutually agreed upon tolerances should be worked out so that the performance and life under given conditions can be predicted.

j. Other Causes

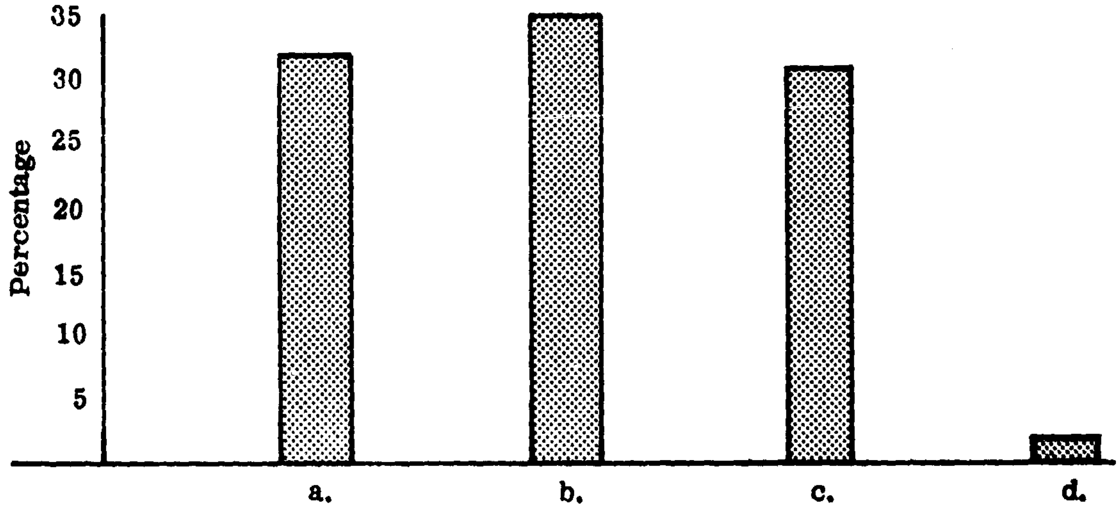
Several respondents assigned fairly high percentages to other causes, notably handling damage and electrical failure.

Rope and cable of the most rugged construction can be damaged by poor handling practices and equipment.

Electrical failure can result from a number of causes. Some form of failure frequency analysis, along with a design, manufacturing, and test procedure review, could be used to help pinpoint specific problems.

3. FAILURES DUE TO RELATED EQUIPMENT

	(Percentages assigned) AV.	HI.	LO.
a. Winch problems (speed, capacity, control, etc.)	32	100	10
b. Sheaves and Blocks (wrong throat size, diameter too small, improper material, etc.)	35	100	5
c. Fittings (improper size, improperly attached, wrong material, type of fitting, etc.)	31	100	5
d. Other	2	40	20



a. Winches

The idea of wrapping a flexible tension member around a drum in order to control the movement of a load has been with us for a long time. Although progress has not been revolutionary, the incorporation of advancements in states of the art in other fields such as metallurgy, hydraulics, and electronics, coupled with the experience gained through widespread use of winches in years of every-day service, has led to steady improvement in capability and reliability of the device.

Oceanography presents unique problems to the winch manufacturer and user. In few other applications does one find the requirement for lowering or raising an object 30,000 feet or more through a hostile environment in which visual monitoring of progress cannot be maintained. That such feats can be accomplished is a credit to the makers and the users of the equipment involved.

However, problems do occur, and the need exists for means by which information as to cable load, package position and behavior, and line scope, can be transmitted quickly and accurately to the control station.

b. Sheaves and Blocks

Many compromises must necessarily be made with the ideal arrangement and configuration for cable systems when the platform is a seagoing vessel. This often results in wrapping the cable through sizable angles around a series of blocks and sheaves. The effect of such bending upon the fatigue life of the cable unless the bends are of generous radius is well known. Cable diameter, construction, and material on one hand dictate desirable sheave sizes, while ease of handling, available space, and cost influence the allowable sizes.

The low factors of safety with respect to the cable which can be permitted in many phases of oceanographic work recommend special attention to the related tackle. Free running bearings, provision for lubrication, design of equipment to permit quick changes of sheaves to suit changes in cable size, and adequate fairleads and cable guards are some of the items which should be given consideration beyond that normally allotted for conventional marine service.

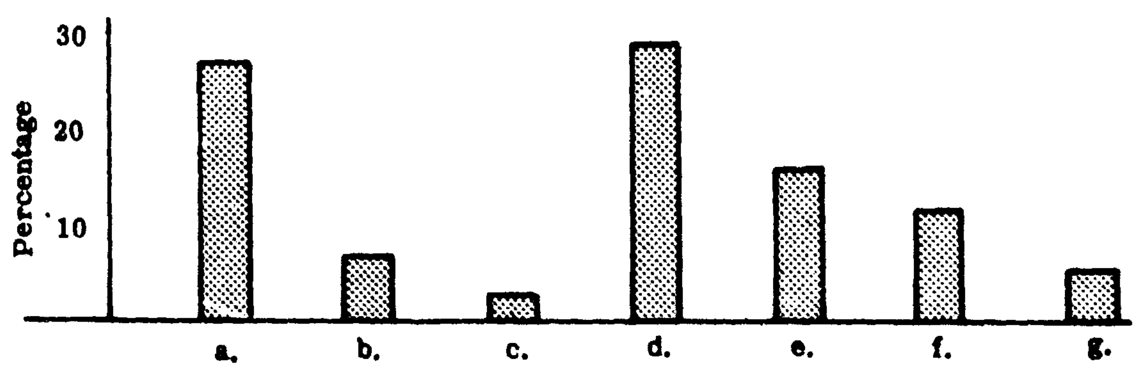
c. Fittings

The performance and reliability of the cable termination at the package is as important as that of any other part of the cable system. The design of termi-

nators and their methods of attachment have been the subject of much investigation. For the most part attachment still remains a matter of skill in carrying out certain recommended procedures developed by trial and error. More knowledge regarding the motions and stresses applied to this link between the load and the flexible supporting member would do much to promote solutions to the causes of failures in this area.

4. FAILURES DUE TO OPERATING TECHNIQUES

		(Percentages assigned)		
		AV.	HI.	LO.
a.	Insufficient information and training available to operating personnel	27	80	5
b.	Improper techniques due to substitution of equipment	7	60	5
c.	Improper techniques due to emergency substitution of personnel	3	30	5
d.	Unusual operating conditions for which no standard procedure has been established	29	100	5
e.	Poor handling or storage procedures	16	75	5
f.	Lack of adequate maintenance procedures (lubrication, adjustment, cleaning, etc.)	12	90	5
g.	Other causes	6	60	10



The provision of good equipment will contribute greatly to the success of any task, but the final difference between success and failure in all manually controlled operations lies in the knowledge, skill, and experience of the operator.

New assignments involving different equipment in a variety of environmental conditions appear to be the lot of the oceanographer. Where possible, equipment designed and constructed or modified to do a specific job should be provided, and personnel trained in the specific task should be employed. There is a tendency, where a variety of conditions is encountered, to "play it by ear". In some cases this is the only possible procedure, and the ability to perform in this manner is an asset not to be belittled. However, the time spent in establishing standard procedures and training operators often reduces the problems encountered in even moderately routine operations. This is merely an extension of the well known "Plan Ahead" adage which is usually worth while when any of the pending conditions of operation can be foreseen.

Information regarding proper handling and storage procedures for cable should not only be available but should be displayed where it cannot be overlooked. With the long lengths of cable involved in oceanographic work, too much money is involved to permit learning the hard way. Repairs are time consuming and, although skillfully accomplished, often result in some degradation of cable performance or life.

Good operators with good equipment in good condition are three essentials for good performance. Everyone knows this applies to all types of endeavor. Periodic inspection and maintenance have produced reliable operation in many fields, most notably perhaps in the aviation industry. How much insurance of this nature is economically sound varies with the nature of the task, but it is a point worthy of consideration.

5. OTHER CAUSES

In the category of other causes, some respondents made comments seemingly to emphasize points which they did not believe to be adequately covered elsewhere. For example:

It must be emphasized that these estimates are based on the relatively small number of cases in which a portion of a lost mooring is later recovered. The recovered portion may have been adrift for a long time, and may have been further damaged or corroded in the interim. The lost gear which is not recovered may carry clues to other modes of failure.

---*---

Generally (almost always) failures are due to overloads in:

a. bending (fatigue) and bending beyond elastic limit — 90%

b. tension

c. tension cycling above endurance limit where (a) is due to cycling over too small pulleys — 10%

---*---

a. Excessive winch speeds — 30%

b. Sudden "stops" and "starts" of winch reel — 20%

c. Spooling device not properly tended or adjusted, thereby allowing sharp angles of the wire going onto the winch drum while hauling in, stacking extra turns on top of each other, cutting through the stack and creating unnecessary chafing and friction damage — 50%

---*---

Lack of information provided rope manufacturers relating to the over-all operation of systems — 100%

---*---

We have experienced a lot of trouble with cable failure at the point at which it is attached to the instrument package (fish). We tow an EDO-Braincon fish at 100 to 500 feet with a pull of 1000 to

5000 pounds at speeds of 4 to 10 knots. The best we have done is about 400 to 500 hours before retermination. We are actively working on this problem. This is a combination of fatigue, stress concentration, fairing, corrosion, etc.

---*---

a.	ship motion in bad weather	40%
b.	improper spooling of wire on winches	50%
c.	defects in wire	10%

---*---

In our work, most all cables are used in a marine environment and subjected to hydrodynamic vibration which is the prime factor in cable failure. A full understanding of the mechanics involved is not presently possible. Various programs are underway to further progress in this area, but more effort is still required.

---*---

6. TROUBLE AND FAILURE REPORTING PROCEDURES

		(Percentages assigned)		
		AV.	HI.	LO.
a.	Written trouble and failure reports	46	100	3
b.	Verbal reports from user at time of failure	26	90	10
c.	Verbal reports from user at time of personal visit from staff members	24	95	7
d.	Other	4	50	20

The most usable history of trouble and failure can be accumulated by the completion and submission of a prepared form as soon as possible after the occurrence. This permits a prompt follow-up for additional information where warranted, since some types of trouble may be difficult and time consuming to

describe accurately, and sufficient detail may not be supplied unless it is known that the occurrence will receive more than passing attention. However, the prompt follow-up will serve to complete the understanding of what occurred as well as afford an opportunity to examine damaged parts in their immediate condition.

Data of this nature can be accumulated and organized for subsequent study to point out the areas of recurring trouble.

In serious mishaps a verbal report from the user at the time of failure, followed by the written report to an established format, will serve the functions of obtaining prompt corrective action, notifying other users of possible hazards, and recording of the occurence for reference in future development efforts.

7. TYPE OF SERVICE

		(Percentages assigned)		
		AV.	HI.	LO.
a.	Towing (data gathering, sweeping, etc.)	28	100	2
b.	Mooring (buoys, mines, sensing devices, etc.)	25	100	3
c.	Bracing (towers, trusses, masts, etc.)	13	100	10
d.	Material handling (cargo, small boats, sounding devices, instrumented packages, etc.)	29	100	5
e.	Other activities	5	95	5

As a matter of general interest, the above information was solicited from the recipients of the survey sheets. It is significant in pointing out the major spheres of interest of the respondents and serves as a guide in evaluating the percentages assigned to the various failure causes.

SECTION IV

CONCLUSIONS

From the summary of the various categories of failure cause, it appears that the cable itself is the greatest offender, with equipment and operating procedures about equal to each other but somewhat less of a factor. This was a reasonably predictable result when the various requirements of oceanographic cables were considered.

There is an indication that the practice more frequently than not is to use available equipment that comes close to meeting the requirements rather than to pay the price in time and money for more nearly ideal components. Often the design of a more desirable part has been established, but little or no testing has been done upon a sample or prototype. Here the user faces the choice of continuing with the known limitations of the older design or taking a chance that the new design will not develop serious unforeseen difficulties in service.

The problem of introducing new designs can be alleviated by more knowledge regarding the loadings and behavior of existing and proposed systems. There is an urgent need for a means of conducting laboratory tests of components and assemblies under simulated service conditions. Instrumentation should be provided to obtain quantitative measurements of pertinent data in both field and laboratory testing.

With regard to operating procedures, sufficient has been said about the value of training and standardized procedures. Here again, laboratory-type controlled operations would produce valuable knowledge as to the peculiarities of a given system in order that operators can be made aware of the best course to follow in difficult situations.

From the standpoint of the cable, corrosion, type of construction, fatigue, and shock are the areas of greatest concern. These have been covered previously to some extent in this report. A great deal of work has been done in investigation and development of cables to solve these problems. Further efforts to avoid a long time gap between development of equipment and its service use would be of benefit. Equipment manufacturers generally are disappointed by the small amount of feedback which they receive from users regarding field performance; they look forward to working with oceanographers to improve their products.

SECTION V

RECOMMENDATIONS

SPECIFIC RECOMMENDATIONS RESULTING FROM THE STUDY

This study indicates that additional information regarding cable systems is needed. In addition, a means of distributing such information to interested parties throughout the oceanographic field should be initiated.

Specific recommendations are:

1. Develop a means for laboratory testing of cables and fittings under simulated field conditions.

2. Introduce a system of trouble and failure reporting using an established format. Set up an index and storage system for the information received so that it can be made readily available for reference. Electronic data processing offers possibilities for this purpose.

3. Periodically distribute bulletins similar to the present Instrument Fact Sheets (IFS's) but pertaining to operational problems, their hazards, and possible solutions.

4. Prepare and distribute a manual outlining the important do's and don'ts of cable handling, equipment maintenance, and winch operation as they apply to the oceanographic field.

5. Develop a system to assist winch operators in avoiding cable slack in adverse sea conditions.

6. Develop a means by which the proximity of a line-held package to the surface of the water can be ascertained. Equip the system with an audio-visual indicator to signal the approach of the package to a critical position.

7. Develop a means by which the underwater action of the various types of oceanographic cable systems and related packages can be monitored during operation. Instrumentation, photography, closed circuit television, and direct observation are among the methods which should be investigated.

8. Expand the study to permit a trained engineer with background in winches and cable to work with the users of cable systems in an oceanographic environment so that data can be assimilated in a more scientific manner to accomplish the following:

a. Reduce the effect of personal opinion in failure reports.

b. Set up a practical format for data to be kept on cables in service.

c. Set up a usable and comprehensive format for failure reports on cable and related equipment.

d. Submit a supplement to the present study based on the findings of the expanded investigation.

SPECIFIC RECOMMENDATIONS FROM VARIOUS RESPONDENTS

Recommendations and suggestions by various respondents to the survey sheet are typified by the following (some have been paraphrased):

1. Application of premium-priced corrosion resistant alloys may be economically justified in many cases.

2. System designs should consider shock loads, bending radii, and working loads of cable.

3. Develop better (cable) constructions suited to oceanography.

4. Enclose information regarding type of construction, material, proper handling, and care in each spool of wire.

   Provide a good compound to dry up the salt water and restore preservation as the wire rope is being reeled in.

5. Thoroughly investigate the entire system and all operating conditions as they apply to the capabilities of wire rope.

6. No major problems with deep-sea trawling cable since switching to U. S. Steel Seale Monitor AA-Amgal torque balanced elevated elastic limit wire rope.

7. Insure that the cable design facility is informed of the exact nature of the application including detailed analysis of all expected service problem areas.

8. Get qualified personnel to make the designs and decisions.

9. Better fairing for towed lines, better terminators for physically attaching to instrument packages, better low maintenance winches, better placement of winches on ship in many cases, and better winch operation.

10. Conducting cables: The external appearance of conducting cable gives little indication of cable condition. Ideally it might include:

a. a transparent insulation.

b. a stress indicator which breaks into short lengths (10- to 0.1-inch) as a function of maximum stress. This could be seen through the insulation.

c. a marker dye around the conductors which becomes colored in the presence of a short circuit or of a low earth resistance.

d. a greater crushing resistance when wound on a drum.

Non-conducting cables.

a. Pressed (stamped) metal drums for transport and storage. (Wooden reels too fragile for shipboard handling).

b. Method of marking which can be detected by a sensor on the winch. This would assist in winch control during night operations. It would be used to mark the cable at a fixed distance above instruments strung on the cable.

11. Improve winch control; improve handling procedures and maintenance.

12. Better strength to O. D. ratio (min. drag). Non twist (possibly braided), non-corrosive, permitting approximately 6-inch-radius bends, co-axial if conducting, with ease of outlets. Fairing of practical shape and size needed for high speed (water) current in surface layers.

13. Improvement of equipment other than cable. Use of qualified personnel. This would involve an extensive training program. If - - - - they alone were allowed to operate oceanographic equipment, increased cable and equipment life could be expected.

14. Cable clips are no longer used. Preformed guy grips; press-type (swaged) fittings, factory applied; and sockets are now used exclusively. Improved guy cable performance from an electrical and structural point of view can be achieved through the use of dielectric guys.

15. Need cable without rotation tendencies under varying loads; that is, sufficiently "round" to allow multi-layer spooling and having dimensional tolerances which permit use on grooved drums with current level winding equipment.

16. Introduce 3 × 19 construction wire rope, and provide constant tensioning device on winch.

17. It is a continuing problem to assure that personnel are trained to handle wire rope properly.

18. Eliminate use of stainless steel and other pitting metals for wire rope to be used in sea water. Develop a non-torquing construction to eliminate kinking. Standardize sheaves and blocks - - - with sealed bearings. Develop winding systems that do not scuff cables and really do level wind. Develop efficient and "clean" systems for properly lubricating wire rope; system should be permanently installed at stowage drum.

SECTION VI

BIBLIOGRAPHY

Anderson, W. F., Feasibility of Application of Titanium to Wire Cable Fabrication, U. S. Navy Marine Engineering Laboratory Report No. 84/66, Feb. 1966.

Brown, B. F. et al, Marine Corrosion Studies, U. S. Naval Research Laboratory Interim Reports July 1964, Nov. 1964, July 1965, May 1966.

Czul, E. C. and Gennari, J. J., Load Carrying Terminals for Armored Electric Cables, U. S. Naval Research Laboratory Report 6261, Aug. 1965.

Fisher, F. H. and Mundy, C. S., "Uniclamp, a Load Bearing Termination for Oil Well, Logging-type Cables", Journal of Marine Research, Vol. 21, No. 2, May 1963.

Gibbons, Thomas et al, Evaluation of Two Methods for Predicting Towline Tensions and Configurations of a Towed Body System using Bare Cable, David Taylor Model Basin Report 2313, Dec. 1966.

Hagarman, P. and Kressley, L., Evaluate, Test, and Manufacture an Improved Wire Rope and Cable, Texas Instruments, Inc., July 1967.

Holmes, P., Mechanics of Raising and Lowering Heavy Loads in the Deep Ocean; Cable and Payload Dynamics, U. S. Naval Civil Engineering Laboratory Technical Report R433, Apr. 1966.

Hoover, H. M., "Wire Rope, A Knotty Problem", Geo-Marine Technology, Feb. 1965.

Little, A. D., Inc., Some Design Considerations for Deep Water Suspension Lines, Dept. of the Navy, Bureau of Ships Report No. 3030365, Mar. 1965.

McClelland, A. E., "The Causes and Prevention of Failure in Wire Ropes", Transactions, Barnsley Mining Students Society, Feb. 1958.

Muraoka, J. S., Deep Ocean Biodeterioration of Materials, U. S. Naval Civil Engineering Lab.; Part I, Nov. 1964; Part II, August 1965; Part III, Feb. 1966; Part IV, June 1966; Part V, Nov. 1966.

Poffenberger, J. C. et al, "Dynamic Testing of Cables", Transactions of the 2nd Annual MTS Conference, June 1966.

Rakoff, F. B., Effects of Certain Ship Motions on Cable Tensions in Systems for Handling Submerged Bodies, U. S. Navy Underwater Sound Laboratory Report No. 558, Aug. 1962.

Rather, R. L. et al, "Improved Towline Design for Oceanography", Under Sea Technology, May 1965.

Savastano, F., "Selecting Wire Rope for Oceanographic Applications", Under Sea Technology, Feb. 1967.

Schick, G. B. and Marshall, P. M., "Jacketted Deep Sea Mooring Line", Geo-Marine Technology, Sept. 1966.

Silverman, M. and Frantschy, J. D., "Wire Rope Practices at Scripps Institution of Oceanography", Society of Naval Architects and Marine Engineers, Oct. 1959.

The Colorado Fuel and Iron Corporation, Roebling Wire Rope Handbook, 1966.

Thompson, J. C. and Logan, R. K., Wire Cables for Oceanographic Operations, U. S. Navy Electronics Laboratory Report 1199, Nov. 1963.

United States Coast Guard, *A Study of the Ocean Station Vessel Oceanography Program, Jan. 1964 - July 1967*, Aug. 1967.

U. S. Naval Oceanographic Office, *Minutes of the Wire Rope Meeting*, Apr. 1965.

Waldron, L. J. and Peterson, M. H., "Unique Cathodic Protection System for a Deep Sea Moor", *Materials Protection*, Aug. 1965.

APPENDIX A

Survey Sheets

and

List of Recipients

WIRE ROPE STUDY

Gentlemen:

All American Engineering Company is engaged under Government contract in a study of the causes of wire rope failures, particularly those occurring in marine or oceanographic service.

As a means of gathering data relative to such occurrences, the attached Survey Sheets are offered as a guide to the type of information desired from those actively concerned with such problems.

It is recognized that all partings of the wire rope are not necessarily "failures" of the rope itself, but may come about because of deficiences in other elements of the overall system. Problems with cables and cable operated equipment may be caused, among other reasons, by:

1. Attempts to use the equipment designed for other purposes.
2. Lack of instruction and/or experience related to the particular equipment or operation.
3. Severe environmental conditions.
4. Difficulty in establishing realistic specifications for the required equipment.
5. Equipment or operational compromises due to economic considerations.

Your consideration of factors of the above nature, and completion of the Survey Sheets will be a valuable contribution to the pool of information from which further areas of research, development, and procurement will be determined: e.g., cables, winches, fittings, oceanographic packages, handling equipment, instrumentation, etc.

Thank you for your cooperation in this effort to arrive at a better understanding of what we believe is a problem of mutual interest.

ALL AMERICAN ENGINEERING COMPANY
WILMINGTON, DELAWARE

CABLE (WIRE ROPE) STUDY

Name of Organization:
Address:

Nature of Business:

Name of Person Completing this Form:

Title:
Date:

Information is desired regarding wire rope partings or failures, particularly in marine or oceanographic service. However, significant data regarding failure producing conditions in other types of service will be of value.

1. In your experience covering the use of cables (wire rope) and cable operated devices, how do you distribute the following causes of failure and/or trouble as percentage of the total?

(a)	Cable not suited to the application	____ %
(b)	Related equipment (winches, sheaves, fitting, etc.) not suited to the application	____ %
(c)	Improper operating techniques used	____ %
(d)	Other causes (See Sec. 5)	____ %
		100%

2. CABLE:

For the cases in which the cable was not suited to the task, what percentage breakdown applies to the following:

(a)	Inadequate rated strength	____ %
(b)	Failed due to corrosion	____ %
(c)	Improper selection of cable construction for type of service	____ %
(d)	Failed due to fatigue (bending, strumming, swaying, etc.)	____ %
(e)	Failed due to sudden load application (Shocks)	____ %
(f)	Extremely vulnerable to handling damage	____ %
(g)	Failed due to erosion, scuffing, or other local wear conditions	____ %
(h)	Failed due to lack of effective lubrication	____ %
(i)	Variations in cable quality	____ %
(j)	Other failure causes (describe)	____ %
		100%

3. EQUIPMENT:

Where the winches, sheaves, fittings, etc., were unsuitable, what percentages apply to:

(a) Winch problems (speed, capacity, control, etc.) ____ %
(b) Sheaves and blocks (wrong throat size, dia. too small, improper material, etc.) ____ %
(c) Fittings (improper size, improperly attached, wrong material or type of fitting, etc.) ____ %

100%

4. OPERATION:

In instances involving operating techniques, what percentages of the problems apply to:

(a) Insufficient information and training available to operating personnel ____ %
(b) Improper techniques due to substitution of equipment ____ %
(c) Improper techniques due to emergency substitution of personnel ____ %
(d) Unusual operating conditions for which no standard procedure has been established ____ %
(e) Poc handling or storage procedures ____ %
(f) Lack of adequate maintenance procedures (lubrication, adjustments, cleaning, etc.) ____ %
(g) Other causes (describe) ____ %

100%

5. OTHER:

Where causes other than those of the above categories are considered important, please describe these causes and assign each a percentage representing its frequency in this group. (Attach additional sheets if desired).

100%

6. REPORTING PROCEDURES:

When problems occur with equipment which you use or supply, what percentage of this information is received by you in the form of:

(a) Written trouble and failure reports ____ %
(b) Verbal reports from user at time of failure ____ %
(c) Verbal reports from user at time of personal visit from members of your staff ____ %
(d) Other (describe) ____ %

100%

7. TYPE OF SERVICE:

As a breakdown of your activities involving the use or supply of cables or cable operated equipment, what percentages are related to:

(a) Towing (data gathering equipment, sweeping equipment, etc.) ____ %
(b) Mooring (buoys, mines, sensing devices, etc.) ____ %
(c) Bracing (towers, trusses, masts, etc.) ____ %
(d) Material Handling (cargo, small boats, sounding devices, instrumented packages, etc.) ____ %
(e) Other activities (describe) ____ %

100%

8. What are your recommendations or suggestions for ways to improve the life and performance of cables (conducting and non-conducting) in oceanographic service?

SURVEY SUMMARY SHEETS

The following tabulation lists the failure causes as taken from the survey sheets and indicates the percentages assigned by the respondents in each category.

64	63B	63A	58	53	48	42	38D	38C	38B	38A	38	36	27	26B	26A
(PERCENTAGES ASSIGNED)															
5	30	60	-	25	50	40	-	15	25	-	-	100	10	60	50
60	30	20	-	25	20	30	10	25	25	100	30	-	10	30	40
35	30	20	-	50	30	20	40	35	50	-	70	-	75	10	10
-	10	-	100	-	-	10	50	25	-	-	-	-	5	-	-
-	10	-	-	-	-	5	-	-	-	-	-	-	-	-	-
10	-	25	20	-	-	30	-	15	-	-	-	-	-	40	80
80	30	75	20	100	10	40	-	-	100	-	-	-	-	-	-
10	60	-	50	-	40	10	40	-	-	-	-	80	10	-	10
-	-	-	-	-	-	5	-	55	-	-	-	10	75	-	-
-	-	-	-	-	-	-	30	10	-	-	-	-	10	-	-
-	-	-	-	-	30	5	-	10	-	-	-	10	5	-	10
-	-	-	10	-	20	5	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-
-	-	-	-	-	-	-	30	-	-	-	-	-	-	60	-
10	20	-	-	-	10	40	-	80	-	-	70	-	75	60	80
30	80	100	-	-	60	35	-	15	50	-	20	-	5	-	-
60	-	-	-	100	30	25	100	5	50	100	10	-	20	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	20
80	10	-	-	25	10	25	30	20	25	-	5	-	15	60	50
10	-	-	-	-	-	5	60	-	-	-	5	-	-	-	-
-	-	-	-	-	-	5	-	-	-	-	30	-	-	-	-
5	60	100	-	-	-	30	-	20	25	-	10	-	80	40	50
5	20	-	-	75	-	25	10	25	15	-	30	-	5	-	-
-	-	-	-	-	90	10	-	30	35	-	20	-	-	-	-
-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	*	-	-	-	*	*	-	-	-	-	-	-	-
3	-	-	-	100	100	60	5	75	50	100	60	-	50	80	80
90	50	50	-	-	-	20	-	-	25	-	20	-	40	-	-
7	50	50	-	-	-	20	95	25	25	-	20	-	10	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	20
-	30	-	-	100	-	15	-	-	-	-	-	-	30	-	-
-	30	50	-	-	-	50	100	-	-	-	10	100	20	100	40
95	-	-	-	-	90	-	-	-	-	100	-	-	-	-	-
5	40	50	-	-	10	30	-	100	100	-	90	-	20	-	60
-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-

24A	24	20	19A	19	10	8	7	6	5	4	3	2	Respondent Code Number
(PERCENTAGES ASSIGNED)													CAUSES OF FAILURE
-	25	50	50	25	50	50	25	15	90	90	95	40	(a) Cable not suited to application
25	10	20	25	50	35	40	20	15	5	5	2	40	(b) Related equipment not suited to t
50	50	20	25	25	15	10	50	40	5	5	3	20	(c) Improper operating techniques u
25	15	10	-	-	-	-	5	30	-	-	-	-	(d) Other causes
													CABLE
-	5	10	-	-	9	5	-	15	30	25	-	-	(a) Inadequate rated strength
20	5	10	-	20	7	-	20	5	10	5	50	10	(b) Failure due to corrosion
-	5	10	10	60	20	75	5	10	60	20	-	10	(c) Improper selection of cable cons
60	20	5	20	-	18	-	20	5	-	25	50	12	(d) Failure due to fatigue (bending, s
10	10	30	35	-	11	-	15	15	-	-	-	50	(e) Failure due to sudden load applic
-	10	-	-	10	15	-	5	10	-	5	-	-	(f) Extreme vulnerability to handling
10	20	20	30	5	13	-	20	10	-	5	-	10	(g) Failure due to erosion, scuffing,
-	20	-	-	-	4	-	10	10	-	15	-	8	(h) Failure due to lack of effective lu
-	5	10	5	5	2	20	2	5	-	-	-	-	(i) Variations in cable quality
-	-	5	-	-	-	-	3	15	-	-	-	-	(j) Other failure causes
													EQUIPMENT
30	75	-	35	20	15	100	20	50	-	10	-	30	(a) Winch problems (speed, capacity,
20	-	100	35	75	50	-	40	25	-	80	50	40	(b) Sheaves and blocks (wrong throat
50	25	-	30	5	35	-	40	25	-	10	50	30	(c) Fittings (improper size, imprope
-	-	-	-	-	-	-	-	-	-	-	-	-	(d) Other
													OPERATION
-	25	50	40	10	24	75	-	15	-	50	25	15	(a) Insufficient information and traini
20	5	-	20	-	19	-	-	10	-	-	-	20	(b) Improper techniques due to substi
-	5	-	-	-	10	-	-	10	-	-	-	10	(c) Improper techniques due to emerg
-	15	10	20	80	14	25	-	5	50	20	25	35	(d) Unusual operating conditions (no s
20	25	40	10	-	29	-	-	20	-	15	25	10	(e) Poor handling or storage procedu
-	25	-	10	10	5	-	-	30	-	15	-	10	(f) Lack of adequate maintenance pro
60	-	-	-	-	-	-	-	10	50	-	25	-	(g) Other causes
*	-	-	-	-	-	-	*	*	*	*	*	-	OTHER CAUSES (Comments included in
													REPORTING PROCEDURE
60	-	50	80	20	-	50	20	40	50	-	-	50	(a) Written trouble and failure report
-	75	-	10	40	50	50	50	10	50	-	-	50	(b) Verbal reports from user at time
40	25	50	10	40	50	-	30	30	-	-	50	-	(c) Field interview with staff member
-	-	-	-	-	-	-	-	20	-	-	50	-	(d) Other
													TYPE OF SERVICE
90	50	90	20	90	5	100	2	20	40	-	10	75	(a) Towing (data gathering equipment,
-	-	-	-	10	-	-	3	50	-	-	90	10	(b) Mooring (buoys, mines, sensing d
-	20	-	-	-	-	-	10	15	-	-	-	10	(c) Bracing (towers, trusses, masts,
10	30	10	80	-	-	-	80	10	60	-	-	-	(d) Material handling (small boats, s
-	-	-	-	-	95	-	5	5	-	-	-	5	(e) Other activities

A

6	5	4	3	2	Respondent Code Number
ES ASSIGNED)					CAUSES OF FAILURE
15	90	90	95	40	(a) Cable not suited to application
15	5	5	2	40	(b) Related equipment not suited to the application
40	5	5	3	20	(c) Improper operating techniques used
30	-	-	-	-	(d) Other causes
					CABLE
15	30	25	-	-	(a) Inadequate rated strength
5	10	5	50	10	(b) Failure due to corrosion
10	60	20	-	10	(c) Improper selection of cable construction for type of service
5	-	25	50	12	(d) Failure due to fatigue (bending, strumming, swaying, etc.)
15	-	-	-	50	(e) Failure due to sudden load application (shocks)
10	-	5	-	-	(f) Extreme vulnerability to handling damage
10	-	5	-	10	(g) Failure due to erosion, scuffing, or other local wear conditions
10	-	15	-	8	(h) Failure due to lack of effective lubrication
5	-	-	-	-	(i) Variations in cable quality
15	-	-	-	-	(j) Other failure causes
					EQUIPMENT
50	-	10	-	30	(a) Winch problems (speed, capacity, control, etc.)
25	-	80	50	40	(b) Sheaves and blocks (wrong throat size, dia. too small, etc.)
25	-	10	50	30	(c) Fittings (improper size, improperly attached, wrong material, etc.)
-	-	-	-	-	(d) Other
					OPERATION
15	-	50	25	15	(a) Insufficient information and training available to operating personnel
10	-	-	-	20	(b) Improper techniques due to substitution of equipment
10	-	-	-	10	(c) Improper techniques due to emergency substitution of personnel
5	50	20	25	35	(d) Unusual operating conditions (no standard procedure established)
20	-	15	25	10	(e) Poor handling or storage procedures
30	-	15	-	10	(f) Lack of adequate maintenance procedures (lubrication, adjustment, etc.)
10	50	-	25	-	(g) Other causes
*	*	*	*	-	OTHER CAUSES (Comments included in Section III)
					REPORTING PROCEDURE
40	50	-	-	50	(a) Written trouble and failure reports
10	50	-	-	50	(b) Verbal reports from user at time of failure
30	-	-	50	-	(c) Field interview with staff member
20	-	-	50	-	(d) Other
					TYPE OF SERVICE
20	40	-	10	75	(a) Towing (data gathering equipment, etc.)
50	-	-	90	10	(b) Mooring (buoys, mines, sensing devices, etc.)
15	-	-	-	10	(c) Bracing (towers, trusses, masts, etc.)
10	60	-	-	-	(d) Material handling (small boats, sounding devices, etc.)
5	-	-	-	5	(e) Other activities

B

RECIPIENTS OF CABLE STUDY SURVEY SHEETS

Cdr. H. S. Placchi, Code 00C
Superintendent Salvage USN
Naval Ships Systems Command
18th & Constitution Aves.
Washington, D. C.

Mr. Joseph Thompson, Code 3118E
U. S. Naval Electronics Laboratory
San Diego, California 92152

Mr. Paul B. Stimson
Research Associate
Woods Hole Oceanographic Institute
Woods Hole, Massachusetts 02647

Mr. H. W. Clapper, President
Bergen Wire Rope Company
Gregg Street
Lodi, New Jersey 07644

Mr. Jeffery Frautschy
Assistant Director
Scripps Institute of Oceanography
La Jolla, California 92038

Mr. A. J. Goodhart
U. S. C&GS Discover OSS-2
Berth 10
Army Base
666 Sumner St.
Boston, Mass. 02100

Mr. J. T. Smith
Bethlehem Steel Corp.
East 3rd Street
Room 127E
Bethlehem, Penna. 18018

Dr. Robert Stevenson
University of Marine Sciences
1 Rickenbacker Causeway
Miami, Florida 33100

Mr. A. H. Crane, Mgr., Electro-Mech. Div.
Rochester Ropes, Inc.
Culpepper, Virginia 22701

Mr. I. L. Snedeker
Marsh & Marine/Vector Cable Co.
Marine Cable Division
5616 Lawndale Avenue
Houston, Texas 77023

Mr. Denzil Pauli, Code 408T
Office of Naval Research
Washington, D. C. 20360

Mr. Samuel Raymond
Benthos
N. Falmouth, Mass. 02556

Mr. Richard J. Anderson
Ass't to Dir. of Marine Sciences and Ocean Eng.
Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201

Mr. K. W. Drummond
Texas Instruments, Inc.
1875 Connecticut Ave., N. W.
Washington, D. C. 20000

Mr. Mark Kurtz, Code 6137
Naval Ship Engineering Center
Main Navy Building, Room 3608
Constitution Avenue
Washington, D. C. 20000

Mr. R. Griffith
R. A. N. Experimental Lab.
New Beach Road
Edgecliff, NSW
Australia

Dr. A. E. Collin, Director General
Maritime Forces, Canadian Forces Hdqs.
Carpier Square
Ottawa, Ontario, Canada

Mr. T. Hirata
Marubun & Co., Ltd.
L, 2-Chome Odemmacho
Ninombashi Chou-ku, Tokyo, Japan

Mr. V. L. Grimoldby
Mgr., Marine Instrument Dept.
The Plessey Co., Ltd.
Uppark Drive, Ilford
Essex, England

Mr. M. J. Tucker
Director Applied Physics Dept.
National Institute for Oceanography
Surrey, England

Mr. Bruce A. Tast
Asst. Research Oceanographer
Physical Oceanographer
Geophysical Institute
University of Tokyo
Binkyo-ku
Tokyo, Japan

Mr. Hellmuty A. Sievers
Institute Hidrografico
De La Armada
Casille 324
Valparaiso, Chile

Dr. Gerold Siedler
Institute fer Meereskunbe
der Universipate Kiel
23 Kiel, den
Niemannsweg 11, Germany

Dr. J. J. Foster
Department of Agriculture & Fisheries of Scotland
Marine Laboratories
Aberdeen, Scotland

Mr. Adolfo Gambardella
Filotechnica Salmoiraghi
Via XX Settembre 34/2
Genova, Italy

Mr. R. Frafsetto
Council for National Research Italy
Oceanographic Buoys Research Program
USEA Building
San Terenzo, La. Spezia, Italy

Mr. Frank Lebel
Aeromaritime Electronique
57 Avenue D'lena
Paris, 16 E. France

Cdr. Charles Glass
U. S. Coast Guard Headquarters - Station 5-5
1300 E. Street. N. W.
Washington. D. C. 20591

Dr. B. F. Brown
U. S. Naval Research Laboratory
Washington. D. C.

Mr. B. W. Forgeson
U. S. Naval Research Laboratory
Washington. D. C.

Mr. L. F. Whicker
U. S. Navy David Taylor Model Basin
Washington. D. C.

Mr. Kenneth Gray
U. S. Naval Civil Engineering Laboratory
Port Heuneme. California

Mr. James S. Miraoka
U. S. Naval Civil Engineering Laboratory
Port Heuneme. California

Mr. Fred W. Reinhart
U. S. Naval Civil Engineering Laboratory
Port Hueneme. California

Mr. Willard Bascom
Ocean Science and Engineering. Inc.
Ocean Science Bldg.
4905 Del Ray Ave.
Washington, D. C. 20014

Mr. Paul McCarthy
24 Fish Pier
Boston. Massachusetts 02210

Mr. Chris Christensen
Pier 4
New Bedford, Massachusetts 02740

Mr. Stanley N. Dulong
122 Wheeler Street
Gloucester, Massachusetts 01930

Mr. Walter Bruce
Homers Wharf
New Bedford, Massachusetts 02740

Mr. Harry Christensen
Custom House Wharf
Portland, Maine 04100

Westerbeke Fishing Gear Co.
Duncan Street
Gloucester, Massachusetts 01930

The Harris Company
188 Commercial Street
Portland, Maine 04100

Towing Problems Branch
Naval Ships Research & Development Center
Carderock, Maryland

H. E. Nash
Naval Underwater Sound Laboratory
New London
Connecticut 06301

Mr. Hardwick Shipley
Naval Ships Engineering Command
Main Navy Building
18th and Constitution Ave., N. W.
Washington, D. C.

AUTEC Manager
Naval Ships Research & Development Center
Carderock, Maryland

Capt. R. T. Miller, Commanding Officer
Navy Mine Defense Laboratory
Panama City
Florida 32401

Mr. Arthur Brisbane
Hydrospace Research Corp.
5541 Nicholson Lane
Rockville, Maryland 20850

Mr. E. A. Capadona
Preformed Line Products Co.
Cleveland, Ohio 44100

Metals & Controls, Inc.
9409 Forrest Street
Attleboro, Massachusetts 02703

Hackensack Cable Corp.
110 Orchard Street
Hackensack, New Jersey 07601

Mr. J. D. Ingram
Exploration Dept.
Shell Oil Co.
New Orleans, La.

Mr. W. A. Boudreaux
Supt. of Transportation
Shell Oil Co.
New Orleans, La.

Mr. Peter E. Weber
Columbia University [illegible]on Labs.
Dobbs Ferry, N. Y.

Mr. A. J. Bartholomew
Packard Electric Div., Gen'l Mtrs. Corp.
Warren, Ohio

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) All American Engineering Company	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

A STUDY OF THE CAUSES OF WIRE ROPE AND CABLE FAILURE IN OCEANOGRAPHIC SERVICE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final

5. AUTHOR(S) (Last name, first name, initial)

Powell, Robert B.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1967	42	

8a. CONTRACT OR GRANT NO. N62306-67-C-0287	9a. ORIGINATOR'S REPORT NUMBER(S) N-576
b. PROJECT NO. c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Naval Oceanographic Office Washington, D. C.

13. ABSTRACT

A study has been made, through a literature search and a survey of users and manufacturers, of the causes of failure of wire rope in marine and oceanographic applications. Although the material, construction, and application of wire rope were symptomatic of the majority of causes of failure, incorrect operating procedures and improper choice of related equipment were large factors. Recommendations are made for further investigation and development to improve performance and reliability.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Wire rope						
Cable						
Oceanographic						
Failure causes						
Stress						
Corrosion						
Winch						
Mooring						
Towing						
Fittings						
Operating procedure						
Reporting procedure						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

Unclassified
Security Classification